• Equation ii of Lochiel and Calderbank does not reduce to the single sphere solution upon letting $E = 0$, while my Eq. 46 does.

• The solution of Lochiel and Calderbank does not provide a distribution of the heat-transfer rate over the surfaces of the cap as given in my Eq. 41 and Figure 3 of the article.

• The difference between the characteristic length of the dimensionless numbers of my equations and those of Lochiel and Calderbank needs correcting Figure 6 of the article to the one shown, which still shows the difference between my solution and that of Lochiel and Calderbank; however, the equation of Lochiel and Calderbank becomes

$$Nu/(Nu)_s = 2.454\frac{(3E^2+4)^{2/3}}{E^2+4}$$

when the dimensionless numbers were based on the curvature of the spherical-cap bubble.

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BOOK REVIEWS

Applied Fluid Mechanics

By T. C. Papanastasiou, Prentice-Hall, Englewood Cliffs, NJ, 1994, 520 pp.

This book is intended as a textbook for a first course in fluid mechanics at the undergraduate level. There is an emphasis on topics used for the materials processing area, particularly from the author's research interests. Chapter 1, "Introduction to Fluid Mechanics," briefly describes the common terms used in fluid mechanics. Chapter 2, "Fluid Statics," covers the usual topics with an interesting section on fluid interface problems. Chapter 3, "Mass, Energy and Momentum Balances," would be more aptly described as a control volume approach to modeling fluid flow problems. Chapter 4, "Viscous Flow and Friction: Confined, Open, Free Stream and Porous Media Flows," covers a variety of problems including friction coefficients, atomization, compressible flow, and pumps. The first four chapters comprise what could be called the "macroscopic" view of fluid mechanics. The next section of the book develops the detailed flow structure equations used on a variety of example problems. The chapter on "Introduction to Differential Fluid Mechanics" uses a shell balance approach to introduce some basic laminar flow equations for simple geometries. Chapter 6, "Unidirectional Flows," examines basic one-dimensional flow situations: radial, slit and tube flows. Chapter 7, "Two-Dimensional Laminar Flows: Creeping, Potential, and Boundary Layer Flows," covers a broad spectrum of problems that show relevant simplifications of the Navier-Stokes equations. The rest of the book is application-oriented starting with chapter 8, "Nearly Unidirectional Flows: Lubrication and Stretching Flows," that covers the lubrication approximation as applied to various material processing problems. Fiber spinning is used as an example to develop equations suitable for stretching flows. Chapter 9, "Rheology and Flows of Non-Newtonian Liquids," discusses various constitutive equations for generalized Newtonian fluids, and there is some introductory material on viscoelastic fluids. Finally, "Turbulent Flow and Mixing" is a brief chapter that introduces the time-averaged flow equations, some empirical mixing models for tanks and some discussion on laminar stretching of fluid elements.

The book is not easy to read. Text material is covered at an advanced undergraduate mathematical level. The discussion is uneven with some topics getting a detailed treatment in the text before being exposed in a problem. Other topics are introduced within a problem solution. Topics are sometimes split and covered in an unexpected order; for example, various forms of the boundary layer equations are introduced early in the book, but the more detailed explanation is not provided until the end of Chapter 7. Some basic equations, such as the Poiseuille flow in a tube, are derived at least twice without reference to the previous derivation. Explanations of basic measurement techniques are not complete and may confuse the student. The author's terminology is sometimes different to that found in many standard texts; for example, the species or mass conservation equations are called the solute mass-transfer equations. There are many typographical errors, some of which could confuse the novice. It would have been better to use a single system of units throughout the book. The index misses some important keywords, and not all the relevant pages are provided for given topics. These difficulties with the book would make me hesitate before I would consider it as a textbook for an undergraduate fluid mechanics course or a materials processing course. The book, however, does have many interesting and challenging problems taken from practical flow situations. Some of the problems can be solved at various levels of simplification and would provide interesting projects for students.

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Numerical Methods for Problems with Moving Fronts

By Bruce A. Finlayson, Ravenna Park Publishing, Seattle, WA, 1992, 605 pp., $60.00.

Some of the most interesting systems described by sets of partial differential equations are those whose solutions display some feature that changes very quickly in a small region of space. One of the classical examples of such systems is the boundary layer of a flow field near a solid wall. Such features are even more interesting and difficult to understand when they arise from physical processes occurring within a domain rather than being forced by external boundary conditions. These systems display "moving fronts," the topic which this book addresses. Of course, in addition to their mathematical complexity, such problems are relevant to describing many technologically important phenomena, as the author points out in its introduction. Such phenomena include reaction zones in catalytic converters, water flow in unsaturated soils, chemical flooding of oil fields, combustion fronts, machining operations, phase change, and many, many more. Interestingly, relatively little headway has been made in the mathematical analysis of such problems, and modern numerical methods have allowed for great progress along the engineering front.

This book provides a good starting point for those interested in solving problems with moving fronts and moving boundaries. In Part I, "One-Dimensional Examples Solved With All Methods," the application and performance of several numerical methods are presented for several example problems, specifically Burger's equation and the convection-diffusion equation. In this reviewer's experience, no other book provides such an exhaustive series of tests of the many numerical methods that may be applied to such problems. On the one hand, this approach is refreshing, and useful results are presented; developers of new algorithms are notoriously lax at testing their performance against other techniques for a suite of test problems under common conditions. On the other, the repetitive nature of these tests makes for rather heavy reading. In conjunction with this portion of the book, some will find the accompanying test programs useful, which allow the reader to repeat the tests on their own personal computer.

Part II, "Applications and Two-Dimensional Examples," is not nearly as focused as Part I. Chapters cover a variety of areas, such as convection and diffusion with adsorption and reaction, phase change problems, the Navier-Stokes equations, polymer flow, and porous media flow. This reviewer had mixed feelings about these chapters. Since each of these topics has inspired entire texts, each chapter represents a rather incomplete account. Consequently, purists will quibble with the choice and focus of many of these chapters. Finlayson, however, does emphasize examples of moving boundaries in these areas and provides rather comprehensive references for those seeking more detailed information. For the student, these chapters may provide a good starting point for the study of these fields.

This book is aimed at novices to the area of moving boundary problems and succeeds as an introductory text. For those who may be interested in a useful companion text, the now-classic *Free and Moving Boundary Problems* by John Crank (Clarendon Press, Oxford, 1984) focuses more on the mathematical formulation of such problems with some examples of solution via numerical methods. All in all, *Numerical Methods for Problems with Moving Fronts* is a worthy addition to the libraries of those who commonly solve such problems or for those who wish to learn how to solve such problems.

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Membrane Handbook

Edited by W. S. Winston Ho, and Kamalesh K. Sirkar, Van Nostrand Reinhold, New York, 1992, 954 pp. $131.95.

The *Membrane Handbook* has been designed as a single source of reference material for the entire field of membrane science and technology, providing both a review of the current literature as well as a detailed description of the currently commercialized membrane processes. According to the editors, it is intended to provide a unified discussion of the underlying principles, membranes, modules, process designs, applications and cost estimates for different membrane processes, thus providing an essential bridge between the theory and practice involved in the development of membrane systems. This is obviously an enormous undertaking; although the authors have not quite met these ambitious goals, they have succeeded in preparing a handbook that should prove to be of considerable value to anyone interested in the use of membranes or membrane processes.

The book extensively discusses the principles and applications of eight existing commercial membrane systems: gas permeation, pervaporation, dialysis, electrodialysis, reverse osmosis, ultrafiltration, microfiltration, and emulsion liquid membranes. It also provides an overview of several new processes under development including membrane-based solvent extraction, membrane reactors, facilitated transport membranes and controlled release systems. In each case, the material has been prepared by leading experts in the respective fields, with many chapters coauthored by individuals from academia and industry for a more complete perspective on the subject matter. The editors have tried to maintain a consistent format throughout the text, with the material on each of these different processes organized into five distinct sections: (1) definitions, (2) theory, (3) design, (4) applications, and (5) cost estimates.

The material included is up-to-date, with a significant number of citations to the literature of the last several years. In all cases, the technical aspects of the presentation are first-rate, and the writing is of very high quality throughout the book. The text itself has been very well prepared and edited, the figures and tables are generally clear and informative, and both the notation sections and index have been meticulously prepared. The tables of available membranes, modules and manufacturers are some of the most extensive compilations of this material published, and they should prove to be an extremely valuable resource to both academic and industrial practitioners. I was particularly impressed with the economic data provided on a number of these membrane processes. This type of cost information is extraordinarily difficult to come by, and the authors have really done a tremendous service in putting this material together in such a usable form.

One of the disadvantages of the editors' decision to organize the material in the *Membrane Handbook* by membrane process is that it obscures many of the underlying themes that connect the general study of membrane science and technology. It also leads to a considerable amount of duplication in discussing topics that cut across different processes. For example, material on membrane casting is provided in at least a half-dozen different chapters, although the focus of the discussion does vary depending on the specific application. More striking is the material on module configurations. The hollow-fiber module is separately discussed in the chapters on dialysis, reverse osmosis, ultrafiltration, microfiltration, gas permeation, and liquid extraction, with a considerable amount of duplication among these presentations and with essentially no cross references to the material in other chapters. In some cases, the presentations of this material were nearly identical: the discussion of the ceramic membrane module in the chapters on ultrafiltration and microfiltration actually used the exact same figure.

One area in which the book falls considerably short of the editors' objectives is in the integration of the underlying theory with the actual process design. In several sections, the discussion of device design provides only minimal reference to the material presented in the